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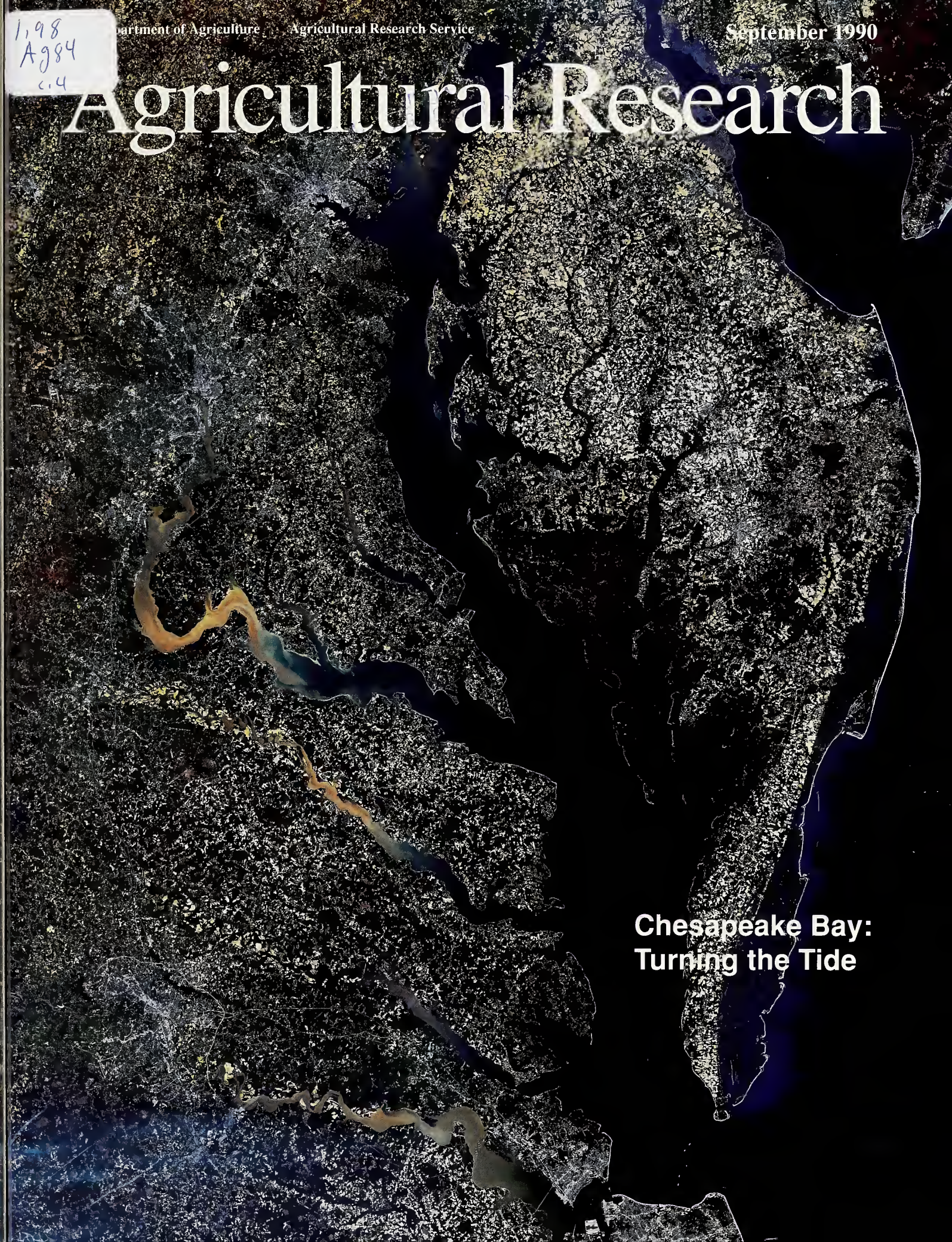


Chesapeake Bay: Turning the Tide

A Coordinated Approach to Water Quality

The detection of agricultural chemicals in water supplies, especially groundwater, has triggered alarm bells throughout the country. Many proposals have been advanced for confronting this issue, even though science has yet to delineate its precise nature and extent.

Is alarm justified? No. Groundwater contamination is not now a serious public health problem. Levels of contamination are well within safe limits in most places at most times.

Is there reason for concern? Of course. Most farmers and many rural communities draw their drinking water from underground. Yet, too many questions remain as to the persistence of agricultural chemicals once they reach groundwater.

Last November, the U.S. Department of Agriculture formed a working group on water quality to improve coordination of the Department's various water quality responsibilities and programs. The working group has bettered not only internal, interagency USDA programs but also joint programs between USDA and other federal agencies, such as the U.S. Geological Survey (USGS), the Environmental Protection Agency (EPA), and the National Oceanic and Atmospheric Administration (NOAA). Research is one of the key areas being coordinated by the working group.

The article on the ongoing Chesapeake Bay cleanup on page 4 of this issue of *Agricultural Research* shows how ARS researchers are working cooperatively with their colleagues in other federal and state agencies to improve the quality of research and the delivery of research results to landowners.

Last year, USDA's Agricultural Research Service and Cooperative State Research Service, in cooperation with the state agricultural experiment stations, published a comprehensive plan outlining their water quality research strategies. The USDA Water Quality Research Plan focuses on protecting groundwater quality through more intelligent use and management of chemicals. Its goals:

- To determine how and why groundwater contamination occurs
- To determine how serious the problems are
- To improve understanding of chemical leaching processes
- To provide timely, cost-effective ways to eliminate existing or potential problems

The plan will expedite development and evaluation of farm production practices that protect groundwater quality; that can be readily adapted to local soil, climatic, cropping, and socioeconomic conditions; and that maintain the economic vitality of agriculture.

One major aspect of the Water Quality Research Plan is a geographic focus on the problems of specific regions. The first of these regional programs is the Midwest Initiative for Water Quality Research.

Why the Midwest? It's one of the most widely farmed areas of the United States. It produces more than half of all U.S. corn and soybeans, two highly chemical-intensive crops when farmed conventionally. Pesticides used by the region's farmers have been detected in groundwater. Groundwater in the Midwest is vulnerable to contamination by nitrate nitrogen as well.

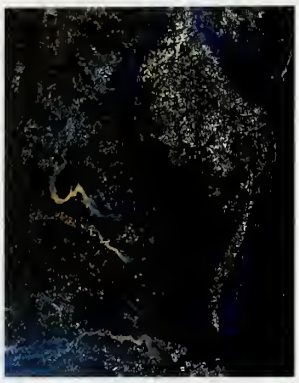
USDA's Midwest Initiative is a combined effort with the USGS Midcontinent Herbicide Initiative for studying groundwater contamination in the central United States. USDA, the state agricultural experiment stations, USGS, and EPA all make up a program management team to provide overall coordination for the research.

The key to research success is not only in finding solutions but also in getting those solutions into the hands of farmers, ranchers, and other landowners. Therefore, new research results will continually be incorporated into USDA's nationwide system of water quality demonstration projects (8 this year, eventually 24) and hydrologic unit sites (37 this year, eventually 275). Demonstration projects and hydrologic unit sites will also help identify new research needs. Economic evaluations of the research results will help researchers and landowners choose practices that best combine resource protection and economic efficiency.

But we must pinpoint the sources and causes of contamination in order to ensure that our research addresses the most serious problems. Policy options for reducing groundwater contamination must be based on a reasoned, scientifically based understanding of the problem—with due consideration not only to environmental quality but also to the economic and social consequences to farmers and consumers.

Harry C. Mussman
Deputy Assistant Secretary for Science and Education at USDA and Chairman of the USDA Working Group on Water Quality.

Agricultural Research



Cover: The Chesapeake Bay as it appears from 438 miles in space from Landsat-5 in the spring of 1987. Features as small as one-fifth of an acre can be seen from Elkton, Maryland to Virginia Beach, Virginia; from Dulles Airport, Virginia to Ocean City, Maryland.
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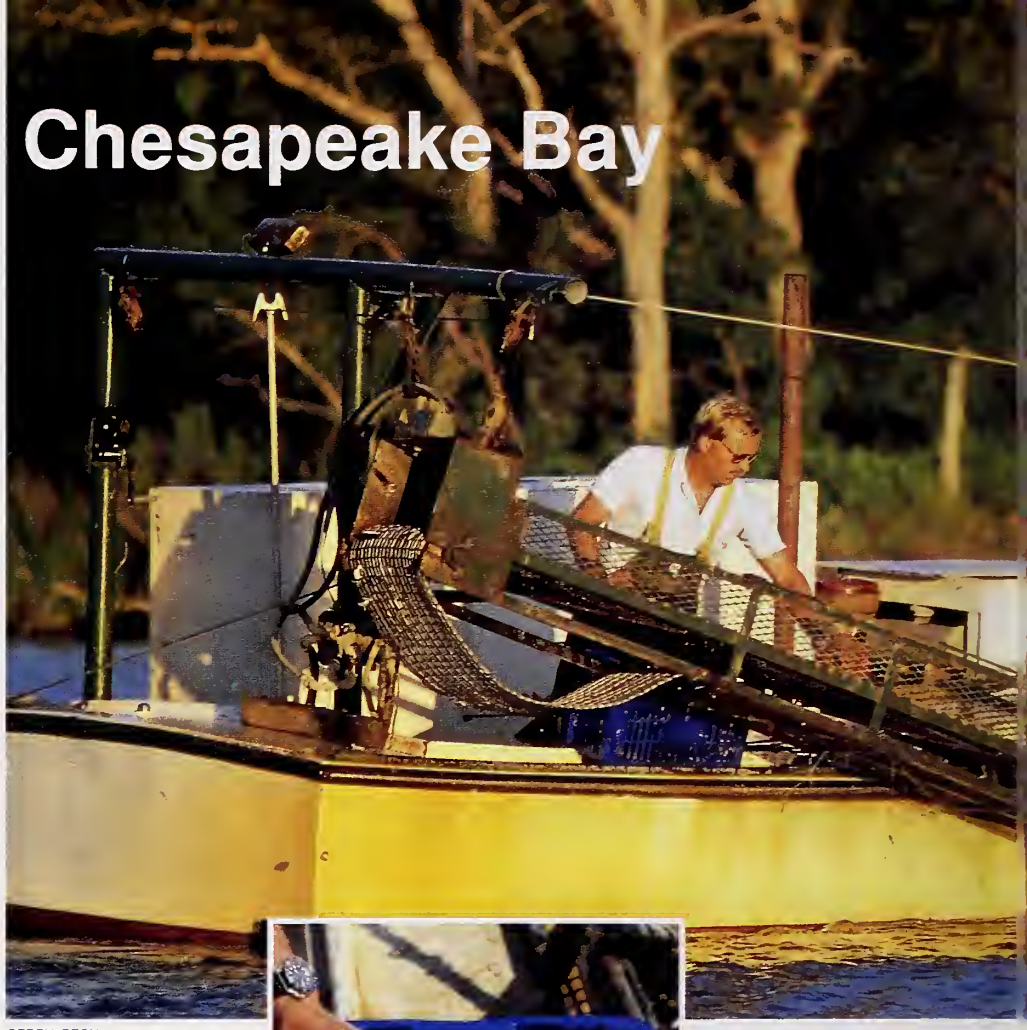
Reviving the Chesapeake Bay



PERRY RECH

When Hurricane Agnes struck in June 1972, the Aquarius was being converted from a Louisiana oil rig crew ship to a Chesapeake Bay research vessel.

Agnes swept along the East Coast, including Maryland, and Pennsylvania where, for several days, heavy rains swelled the Susquehanna River to flood stage.

The sudden flow of so much fresh water and smothering silt was the coup de grace to submerged aquatic grass growing near the mouth of the Susquehanna and to the clams and oysters in the Upper Bay.

These days, Mike Ruesing guides the Aquarius through the Bay year-round. It's a voyage he's regularly made as captain of the University of Maryland's 65-foot research vessel since Agnes.

Headed at 16 to 18 knots toward the last research stop on a day in early April, he reaches the Flats, a shallow area near the mouth of the Susquehanna.

Once crowded with grass so dense that it sometimes interfered with boat traffic, the Flats are now the Chesapeake's version of a desert. Gone is an essential hiding and feeding place for fish.

Ruesing has watched the grass disappear. "Actually, it was mostly gone by the time Agnes struck," he says, turning the vessel's large wooden wheel. The storm tipped the scales on the Bay's weakened ecological state, accelerating a decline from which it is only now beginning to recover.

Larry Simns, president of the Maryland Watermen's Association, agrees. Had Hurricane Agnes struck 25 years earlier, the Bay would have "bounced back real quick." As marine biologists and technicians on board the Aquarius gather data in the Flats, a visitor and the ship's mate discuss the possible price of a group of shoreline townhouses on stilts at Havre de Grace, Maryland.

The summer homes are an example of how people increasingly love the Bay—sometimes to death. In 1950, there were about 8 million people living in the Bay's watershed. Within the next three decades, that number is expected to increase to 16 million. "Agnes accented every problem we had," Simns says. "We had our biggest rockfish hatch the year before Agnes. We survived off that for 15 years after Agnes when the hatches were poor to nonexistent."

Simns says the silt from Agnes kept the Bay cloudy for 2 years. "This blocked out sunlight needed for the zooplankton to survive. It killed all the clams and oysters in the Upper Bay. This added to fishing pressure on the Lower Bay and precipitated a decline there.

At sunrise, just off Love Point on the Chesapeake Bay, waterman Doug Kayhoe dredges the Bay's floor for clams. (K-3692-1) This summer's harvest averaged only about half the allowed 15-bushels-per-day limit. (K-3692-2)

CHARLES PHILLIPS

Aquarius crew member Kelley Cox compares tap water (left) to a water sample taken from the upper Chesapeake Bay at Still Pond. (K-3691-1)

"Now the fish are coming back. There's more shad. The clams came back about 6 years ago. Oysters began rebounding 3 or 4 years ago, but then they were decimated by MSX and Dermo parasites in the Lower Bay. That placed more harvesting pressure on the oysters in the Upper Bay.

"We've got a delicate balance. If you take away one species, the watermen going after that species are not going to quit and take an inland job. They'll just switch to another species. That's why we call them watermen. They're equipped to go after any species, any season. They'll go after crabs, oysters, clams, or fish."

Because of water pollution, the Bay is not reproducing as well as it should, Simns says. "We've been miners rather than harvesters for years after Agnes. But we didn't change the way we operate—the species just didn't rebound."

"It's important to realize the Bay has some of the cleanest water in the world," he says. "The pollution we're talking about is an enrichment problem and that doesn't make food produced in the Bay harmful to consumers. It just makes for less food."

Most of the enrichment comes from either agriculture or the treatment plants that process sewage from the 13 million people living in the Bay's watershed, says Jack Plimmer who is with the U.S. Department of Agriculture. While treated sewage is free of bacteria once it passes through treatment, it carries the selfsame ingredients found in farm fertilizers:

nitrogen, phosphorus, and other nutrients that can cause excessive growth in algae (or phytoplankton).

We're building a compost pile on the floor of the Chesapeake Bay. It's just that simple, says Michael S. Haire, who is with the Chesapeake Bay Project, which is funded by the Maryland Department of the Environment and the U.S. Environmental Protection Agency. It's like fertilizing the whole Bay, he says.

CHARLES PHILLIPS

Captain Mike Ruesing heads north up the Chesapeake Bay to the next water sampling site. (K-3689-6)

Haire's colleagues monitor the Bay from the white deck of the Aquarius for a few days every other week.

In the past few years, EPA and USDA, working with other federal and state agencies, have intensified their commitment to stop the excessive release of nutrients from all sources, as well as the discharge of pesticides, metals, and other pollutants into the Bay, according to Plimmer, who is with USDA's Agricultural Research Service in Beltsville, Maryland.

Compost Under the Sea

"Just compare it to what happens on your lawn," Haire says. "You put fertilizer down each spring or fall to grow a nice lawn. Then you mow it and throw the clippings in a compost pile. Later, when you put your hand in the pile, you find it's very hot. That's from the energy given off by the bacteria eating the grass."

"The same thing happens in the Bay," Haire explains. "Nitrogen—some of it from your lawn fertilizer in fact—enters the Bay and grows algae instead of grass. As the algae die, they sink to the bottom. There, bacteria work on the compost pile."

But there's one crucial difference between your backyard compost heap and the Bay floor. Your backyard has a limitless supply of oxygen. The Bay floor has almost none.

Excessive growth of algae at the surface blocks out sunlight needed for the growth of algae more desirable to fish as food. The lack of sunlight also harms other kinds of submerged vegetation. Light can penetrate no farther than 10 feet in the Upper Bay and about 33 feet in the Lower Bay.

In some areas of the Bay, adequate oxygen extends only a third of the way down, rendering the bottom two-thirds nearly lifeless. The bacteria use up what little oxygen there is as they work on the compost. In doing so, they suffocate fish, clams, oysters, and blue crabs.

Isolating Nutrients

Phosphorus is the most troublesome nutrient in the freshwater parts of the Bay, whereas both nitrogen and phosphorus are potential problems in the brackish places.

Plimmer says scientists typically classify the sources of nitrogen and phosphorus into two groups—point sources and nonpoint sources. Point sources are direct pipe discharges from industry and sewage treatment plants into the Bay or its tributaries. Nonpoint comes from diffuse sources: urban, forest, and agricultural runoff; atmospheric deposition; natural release from Bay bottom sediments; groundwater inflows; and oceanic inputs.

Although costly, control of point source pollution is much easier than nonpoint. Haire says, "It's much more difficult to tell where nonpoint pollution is coming from, how much there is, and how to reduce it."

"In Maryland," he continues, "about 62 percent of the phosphorus entering the Bay comes from point sources, mostly from sewage treatment plants, and the rest from nonpoint sources, mostly from agriculture," he says.

"As for nitrogen, about 48 percent comes from point sources, again mainly from sewage treatment plants, and the rest from nonpoint sources, again dominated by agriculture," he says.

Plimmer, who serves on EPA and U.S. Geological Survey (USGS) committees on the Chesapeake Bay, says the ARS role is to understand this pollution well enough to give farmers more options for reducing it.

From Golf Courses and Smokestacks

It's not surprising that some of the nitrogen comes from fertilizer washed from farm fields. Or even that some comes from the manure of the more than 500 million broiler chickens produced each year on the Delmarva (Delaware-Maryland-Virginia) Peninsula that separates the Bay from the Atlantic Ocean.

But it may seem a little surprising that some of it comes from home and golf course lawns in the Bay watershed, a 64,000-square-mile area

that reaches south of Washington, D.C., to Virginia and as far north as the Susquehanna's headwaters, Otsego Lake, in upstate New York.

Most of the atmospheric sources—coal-burning power plant smokestacks (like those near the first research stop off the Port of Baltimore)—are not surprising. But how about your car's tailpipe? Even when you drive outside the Bay's watershed, say, in Ohio?

Lynn Shuyler with EPA's Chesapeake Bay Liaison Office in Annapolis, Maryland.

Plimmer, head of ARS' Environmental Chemistry Laboratory, has teamed up with colleagues to study how much nitrogen and pesticides are deposited in the Bay from the air.

Alan W. Taylor, Plimmer's predecessor while he was with ARS and now liaison between the University of Maryland and the Chesapeake Bay

"The problem is, dry deposition is difficult to measure."

Nicholas J. Fendinger, an environmental chemist who worked with Plimmer, explains, "One day chemicals may be falling into the Bay, and the next day they're coming out of the Bay. The direction of the traffic depends on complex chemical and physical phenomena, including the weather. It might be as simple as the wind slamming particle-bound

CHARLES PHILLIPS

More than 20 million tons of bulk cargoes traverse the Chesapeake Bay each year. (K-3689-15)

All these sources spew nitrogen oxides into the atmosphere. Some of the oxides are formed when nitrogen escapes as a gas from farm fertilizers spread on fields. And some comes from lightning. Electrical energy causes nitrogen and oxygen naturally found in the atmosphere to combine into molecules of nitrogen oxides.

Acid rain formed by these oxides can damage the Bay and other waterways, not only by increasing the acidity of the freshwater portions but also by adding nitrogen fertilizer, perhaps 12 to 18 pounds or more per acre of watershed each year, says

Commission, pioneered in the study of atmospheric transport of pesticides, along with the late Dwight E. Glotfelty and others at the ARS lab.

He and Glotfelty demonstrated that significant amounts of pesticides could leave plants and soil as vapors in the gaseous state, become airborne, and return to land or water in wet forms such as rain, snow, sleet, hail, or fog. These substances can also be deposited dry, either as gases that dissolve in the Bay or attached to dust or other dry particles.

"There's very little grasp of dry deposition," Taylor reports.

chemicals into the Bay. Chemicals can leave the Bay many ways including when a droplet of water flies off a wave and breaks in the air."

The potential for trouble with these chemicals in the Bay is great: According to the National Oceanic and Atmospheric Administration's National Coastal Pollutant Discharge Inventory Program, the land drained by Chesapeake Bay ranks first among the Nation's 78 major estuarine watersheds in terms of the quantity of pesticides applied; 28 commonly used agricultural pesticides were considered. The watershed

CHARLES PHILLIPS

ranks second when the application of these pesticides is adjusted for toxicity to estuarine organisms.

Haire says the joint state-EPA Chesapeake Bay program has determined that if the 1985 loads of nitrogen and phosphorus were reduced by 40 percent by the year 2000, water quality and hopefully Bay life could be restored to desired levels.

He says the 40-percent-reduction goal was obtained from a computer model that was fed 1985 data from several sources, including monitoring data collected by the Aquarius.

The model has to deal with the complex routes—by land, water, and air—taken by pesticides and nutrients on their way to the Bay.

Filtering Out Pollutants

When chemical-laden rainwater flows through a grassy streambank or wooded swamp or marsh, it can come out almost free of nitrate and possibly pesticides. Studies by ARS and Smithsonian Institution scientists have shown that riparian zones—wooded swamps, marshes, and streambanks—somehow remove nitrogen fertilizer, perhaps using it to grow more trees and grass.

Jim Starr, a soil physicist at the Environmental Chemistry lab, isn't quite sure all or even most of the nitrate is going to the plants because the nitrate disappears fastest in the winter when plants have stopped taking in nutrients.

He suspects the nitrate's main loss is through a process called denitrification. "Microbes use nitrate molecules much as we use oxygen," he says. "This requires a ready supply of organic carbon, which can come

During a study of how nitrates are removed from soil along stream banks, ARS soil scientist Jim Starr injects bromide and nitrate solution into a shallow sampling well. (K-3695-4)

from the decaying plant roots in riparian zones."

To see where the nitrate is going, Starr has designed miniature portable wells that he placed near streams on the Eastern Shore this past summer. The wells are 1-inch-diameter plastic pipes with several tubes inserted at varying depths below the shallow water table.

Plimmer says, "We're looking at nitrate first because we believe it may be more of a problem than pesticides."

As part of a national water quality assessment program, USGS has 200 wells on the Delmarva Peninsula. The peninsula is one of the first of about 60 planned study areas that will be distributed throughout the nation, encompassing about 45 percent of the land in the mainland United States.

Tests are being run for the most common herbicides and insecticides, trace elements, radon, and solvents such as benzene.

A Call for Action

State agencies have already begun to respond. Maryland, Virginia, and Pennsylvania each have nutrient/manure management programs that are beginning to reduce the amounts of fertilizers and manure being used. "We'll have to wait and see what effect that has on the Bay," says EPA's Shuyler.

Mitch Woodward coordinates the nutrient management program for Maryland from the University of Maryland in College Park. Woodward has 14 consultants in extension offices throughout the state who help farmers design fertilization plans. These are based on an analysis of nutrients in the soil and in manure if applied.

Without a soil or manure analysis, farmers often resort to broad rules of thumb that are likely to be inaccurate for their specific circumstances. They realize they are probably overfertilizing, but they see the excess fertilizer as insurance, meaning it's what's needed to be absolutely sure they won't fall short and lower their yields. And sometimes this "insurance" ends up in agricultural runoff.

PERRY RECH

Jeanie Foley, who works at a Chesapeake Bay restaurant, checks soft shell crabs for freshness. (K-3692-3)

Better Soil Tests Can Help

Plants consume large amounts of nitrogen, phosphorus, and potassium—the three key ingredients in commercial fertilizers. Although tests have long existed for phosphorus and potassium, scientists for years were unable to come up with an adequate test for nitrogen in the moist soils of the humid eastern United States and parts of the Midwest.

Most of the phosphorus and potassium taken up by plants is released by dissolution from native minerals in the soil or fertilizer. Large quantities of nitrogen come not only from fertilizer but also by release from organic matter by living microbes.

Soil tests for phosphorus and potassium involve chemical extractions that simulate the weathering process and root uptake to predict the amounts that will be available to plants. But for nitrogen, it isn't easy to mimic the action of microbes with chemical tests.

So to get around this, recommendations for applying nitrogen fertilizer are based on the amount of soil organic matter, yield goals, and soil type. A credit is also made in the recommendation for the amount of nitrogen assumed to be left in the soil by any manure application or legume crop.

Farmers often discount the nitrogen credit for manure and legumes because it's so unpredictable. Manure can lose a third of its nitrogen content in a few days if it's left on the surface and dries out.

So in 1984, Fred R. Magdoff, of the University of Vermont, reasoned it would be better to forget the predictions and just measure nitrate after microbes have had a chance to do their job, yet before plants start taking in nitrogen.

A new test, based on Magdoff's idea, involves taking a soil sample at a 1-foot depth and measuring the amount of nitrate nitrogen in the soil.

Pennsylvania has been using the new test for 2 years, and other states in the Chesapeake Bay drainage area are checking it out.

Soil scientist Jack Meisinger, who is with ARS in Beltsville, has been pleasantly surprised by the accuracy of the test so far.

He says, "It's a big step forward, because it's highly accurate in pinpointing the worst-case fields where losses could occur if more nitrogen is applied. These are fields that have adequate nitrogen already, usually thanks to legumes or manure.

"For example," Meisinger says, "preliminary tests in 1989 have shown that 20 to 25 parts per million nitrate in mid-June is adequate for excellent corn yields."

For corn, a particularly heavy user of nitrogen, the nitrate test is done when the plants are between 6 and 12 inches high. In the Bay area, that's early June.

"We benefit greatly from Jack Meisinger's helping us evaluate the test and sharing other research results on nitrate with us," Woodward says.

Meisinger sees his role as providing data to extension agents and nutrient management specialists such as Woodward and letting them make the interpretations needed to turn the data into practical recommendations.

The rules of thumb developed from these interpretations have been incorporated by University of Maryland and ARS scientists into a computer program that provides farmers and others with expert recommendations on fertilizer needs.

ARS scientists have also worked cooperatively with University of Maryland researchers on no-till corn plots for the past 18 years.

The research helped spread the concept of no-till corn; soon, fields littered with the stubble of the previous crop became a common sight around the Bay. The leftover residue, which has not been plowed

CHARLES PHILLIPS

In a Maryland cornfield at the mouth of the Patuxent River, ARS soil scientist Jack Meisinger (middle) and University of Maryland nutrient management specialists Janine Baratta and Mitch Woodward apply various rates of nitrogen fertilizer to determine the best rate that avoids overfertilization. (K-3694-5)

under as in conventional tillage, retains soil and water just as mulch does for a garden.

Last year, Maryland farmers planted 186,735 acres of "full season" corn without plowing.

"Generally, no-till reduces rainwater runoff, and with it, phosphorus runoff," ARS' Harry M. Kunishi says. "Not to mention the great reduction in soil erosion and other no-till benefits."

Allan Bandel, extension soils specialist at the University of Maryland, says the no-till success in Maryland and other Mid-Atlantic states caused it to spread to other Bay area states and beyond.

But with the change in tillage came a need for other studies: What kind of adjustments should be made in nitrogen and phosphorus recommendations?

Based on the cooperative no-till research Meisinger and colleague Kunishi participated in with Bandel, the University of Maryland has significantly reduced its phosphorus recommendations for no-till corn farmers. The university has also improved its nitrogen recommendations by advising more timely applications and more precise placement of the fertilizer.

Kunishi, who is a research chemist, works with Bandel on improving the university's soil test for phosphorus. "We need a better technique, especially for Eastern Shore farmers," Bandel says.

Another practice that has spread from joint ARS-University of Maryland-Tennessee Valley Authority research is injecting nitrogen into soil rather than spreading it on the surface. "This can often halve the amount of liquid nitrogen needed," Bandel says.

"It's one of the best techniques to come out of our nitrogen management work, which has been done in partnership with ARS and TVA from the very beginning," he says.

Analyzing Chicken Manure

State universities have for many years analyzed soil samples for homeowners and farmers but have never before tested manure. This is quite important in the case of chicken manure, which is potent stuff. Each ton contains about 60 pounds of nitrogen, 60 pounds of phosphorus, and 40 pounds of potash.

In spite of its potential as a pollutant to the Bay, chicken manure is valuable. It's shipped to farms elsewhere in Maryland and as far north as the mushroom farms of Pennsylvania.

"Any excess nutrients not used by crops may ultimately find their way to the Bay. Our nutrient management work is designed to help farmers prevent that."

In fact, whenever a farm is producing more manure than can be used safely, the University of Maryland extension agents and nutrient management consultants try to help farmers make contact with buyers.

And some farms can easily produce more manure than can be used in an environmentally safe way. Woodward had to work at convincing the Amish farmers in Pennsylvania of this when he helped start the nutrient management program there, before coming to Maryland. It was at first hard for these traditional farmers to believe that nitrogen from heavily manured farms could contribute to the decline of the Bay.

"It can be hard for farmers in Pennsylvania or even western Maryland to believe they have an effect on the Bay," Plimmer says. "Our job is to collect the facts on these effects and get them to extension agents and others working with farmers. We're finding that many mundane things, such as nutrient testing and leaving crop residues on fields, go a long way toward a cleaner Bay."

"They keep soil where it is so it doesn't end up in the Bay and its tributaries, choking the water with silt and nutrient-fed algae," Plimmer says. "People don't realize that the small tributaries are essential breeding places for fish and they need to be kept clean and swimmable."

"Any excess nutrients not used by crops may ultimately find their way to the Bay," Plimmer says. "Our nutrient management work is designed to help farmers prevent that."

And Plimmer's lab has been involved in more fundamental Bay-related water quality research, such as improving the accuracy of techniques to analyze pesticides in well and Bay water. "Many of the techniques we're developing in Bay work will be applicable to water everywhere," Plimmer says.

Another new area of research for Plimmer's lab is searching for a biological early warning system for water pollution. "Currently, we're looking at whether we can spot precancerous morphological changes in fish livers for such a warning system," Plimmer says.—By **Don Comis,** ARS.

For addresses or phone numbers of ARS scientists mentioned in this article, contact Don Comis, Agricultural Research Service, Room 331A, Bldg. 005, BARC-West, Beltsville, MD 20705 (301) 344-2773. ◆

Making Oats More Healthful

Oat food products, promoted to the hilt as healthful in recent years, could come even closer to living up to the claims, thanks to research that increases a cholesterol-lowering component of the grain.

Specialty varieties of oats in the future may have elevated levels of soluble fibers called beta-glucans, says plant physiologist David M. Peterson of USDA's Agricultural Research Service.

Animal studies by Peterson and colleagues at the University of Wisconsin showed in the mid-1980's that oats have ingredients that lower cholesterol-bearing low-density lipoproteins in blood plasma (*Agricultural Research*, January 1985, p. 10).

Dietary studies by medical officer James W. Anderson of the Veterans Administration Hospital at Lexington, Kentucky, and by researchers at several other medical institutions have shown these soluble fibers reduce human cholesterol levels.

Genetic resources needed to develop oat varieties high in beta-glucans might be found among the 21,000 oat genotypes in the National Small Grains Collection at Aberdeen, Idaho. Peterson and ARS agronomist Darrell Wesenberg, Aberdeen, have developed assay methods that are needed for preliminary screening of the large collection for beta-glucan concentration within the next year or two. By this winter, the scientists expect to have enough information to benefit plant breeders making crosses in greenhouses.

Peterson and his colleagues are also conducting basic research that may lead to improved screening efforts. The studies may shed light on how the genes involved in beta-glucan synthesis are regulated during various stages of crop growth.

"Someday we hope to identify genes involved in beta-glucan synthesis," says Peterson. That's an early step toward genetically engineered super oats.

In preliminary research, he and Wesenberg found genetic variability in oats that offers promise for improving the crop's nutritional quality through conventional selective breeding. The studies involved growing 12 oat varieties in 8 states from New York to Idaho. In Illinois, where the range of beta-glucan concentration was greatest, Otee, and Hazel varieties produced oats that were some 35 percent richer in beta-glucans than the two poorest varieties, Lodi and Garry.

Some varieties produced large amounts of beta-glucans only when grown in certain regions, but Otee, and Hazel topped most varieties throughout the geographic test range.

Peterson and research associate James L. Koch are trying to learn how enzymes involved in beta-glucan production are affected by genetics and environment. Applying such knowledge in conventional breeding or genetic engineering could lead to new high beta-glucan oat varieties especially adapted for economical production.

Peterson and Koch are looking at the feasibility of using coleoptiles, the first leaf of germinating seed, as a model system to study beta-glucan synthesis. Coleoptiles have beta-glucans similar to those that later form in the grains, and they are produced abundantly over a period of 2-3 days.

In another study, the scientists are trying to learn why oat beta-glucans are more soluble in water than barley beta-glucans. High solubility is important for lowering cholesterol in humans. The researchers have found oats and barley differ in their proportional amounts of two types of chemical bonding that link glucose molecules into a linear chain. Further study may show whether this difference is important.

All 12 oat varieties that Peterson and Koch studied had the same glucose-bonding characteristics, but they found considerable variation among several wild relatives of oats.

Plant physiologist David Peterson examines field plots of oat varieties grown to determine the effects of genetics and the environment on beta-glucans production. (K-3711-1)

BRUCE FRITZ

KEITH WELLER

Frozen desert made with oatrim is prepared by chemist George Inglett. (K-3608-1)

That's a hopeful sign for researchers as they look toward improving the healthfulness of oats through genetic engineering and interspecies crosses.

Oatrim—Even Better

Plans to breed oats for increased beta-glucan content in oats may up the percentage of this fiber in oatrim, a new fat substitute invented at the ARS Northern Regional Research Center, Peoria, Illinois by chemist George E. Inglett.

Made by treating oat bran and flour with enzymes, oatrim gel has one-ninth as many calories as fat. It is designed as an ingredient in dairy products and prepared foods.

Every 30 grams of oatrim from oat bran contains about 2.5 grams of beta-glucans—about the same concentration as in oat bran—By **Ben Hardin,** ARS.

David M. Peterson and James L. Koch are in USDA-ARS Cereal Crops Research, 501 N. Walnut Street, University of Wisconsin, Madison, WI 53705 (608) 262-4482. Darrell Wesenberg is in USDA-ARS Small Grains and Potato Germplasm Research, P.O. Box 307, Aberdeen, ID 83210 (208) 397-4162. George E. Inglett is in USDA-ARS Biopolymer Research, Northern Regional Research Center, 1815 N. University Street, Peoria, IL 61604 (309) 685-4011. ◆

Rescuing Oats' Heart-helpers, Beta-glucans

Using a high-speed grinder and a fine-mesh sieve, ARS researchers have recovered a floury portion of oats that contains an impressively high concentration of beta-glucans. The glucan-enriched portion represents a good yield—it's a respectable 20 to 38 percent (dry weight) of the starting material, says ARS research chemist Benny E. Knuckles at Albany, California.

Studies indicate oats containing beta-glucans have cholesterol- lowering effects. The dry-milling experiments could lead to low-cost production of a new product enriched with beta-glucans, Knuckles says. The product could be a healthful addition to foods that don't normally have cholesterol-lowering properties.

In experiments at the Food Quality Research laboratory, Knuckles worked with either oat bran, containing 9.8 percent beta-glucans at the outset, or the familiar flattened flakes of rolled oats, with 4.8 percent beta-glucans.

After removing the fat from the oats, then grinding them into a flour, Knuckles used the sieve to separate extremely fine particles, high in starch, from larger particles containing a substantial amount of beta-glucans.

With food technologist Antoinette A. Betschart and chemist Mei-Chen M. Chiu at Albany, Knuckles will use larger scale equipment for more dry-milling tests. Those experiments should indicate whether commercial mills could adapt the glucan-enriching process with similar success.—By **Marcia Wood,** ARS.

By milling rolled oats (right) and removing starch-enriched particles, chemist Benny Knuckles obtains flour with high concentrations of beta-glucans. (K-3710-1)

JACK DYKINGA

Tricky Business: Raising Cattle in Florida

MIMI WILLIAMS

Because of its impressive ability to tolerate subtropical heat as well as disease, the Brahman has bee

It seems like a match made in heaven—cattle and Florida: Lush tropical grasses, no frozen watering troughs to hack through, no wintry calving sessions.

But in reality, cattle production in Florida—or anywhere tropical or subtropical—can be tricky. Not that Florida cattle producers aren't able to pull it off; beef production in that state in 1989 totaled 412.06 million pounds, with a value of $336.08 million.

Still, the scientists at the Agricultural Research Service's Subtropical Agricultural Research Station at Brooksville, Florida, hope to make the trail a little smoother. Working in cooperation with faculty of the University of Florida's Institute of Food and Agricultural Sciences, they're striving to improve both cattle and the forages they graze.

Because of its impressive ability to tolerate subtropical heat, the Brahman breed has been a key player in the Florida cattle business. But ARS scientists are evaluating other tropical breeds, with an eye to broadening the genetic base of cattle adapted to the warm areas of the United States.

"Brahmans have resistance to both heat and disease," says ARS animal scientist Andrew C. Hammond, research leader at the Brooksville lab. "The typical Florida cow is a crossbred Brahman.

"The biggest problem with the breed is reproductive efficiency. They have a longer gestation and a longer postpartum period before becoming pregnant again."

It's not unusual for Brahmans in Florida to fail to rebreed in the 3 to 4 months after calving, according to research animal scientist Chad C. Chase Jr. And cattle producers here wait longer for that first calf, too.

"In Florida, we usually breed heifers to calve as 3-year-olds," he notes. "But in other states, they breed to calve as 2-year-olds. The difference is largely due to nutrition, but that's not to say Brahmans could anyway; they reach puberty later."

The Brooksville scientists are considering other types of cattle that might fit the bill for Florida's subtropical setting. Among the possibilities are Senepol, a breed developed on the Caribbean island of St. Croix, and Romosinuano, a breed native to Colombia.

"Senepols first came here in 1977 as semen for crossbreeding. The first females arrived in 1979," Hammond recalls. "We've been building a herd and last year reached our goal of 100 head. We're just starting a 5-year project of crossing Senepol with Herefords."

Like the Brahman breed, Senepol cattle can take the subtropical Florida temperatures and are resistant to gastrointestinal parasites such as stomach worms or intestinal round worms. They also have a better

breed in the Florida cattle business. (K-3714-1)

reproductive track record in their native setting than do Brahmans in Florida, but that advantage may not survive the move to Florida.

"The Senepol in St. Croix efficiently utilize the forages there, and they have a calf every year," Hammond cautions. "But the tropical forages we have to use here because of our tropical summer don't tolerate our winter with frost potential anytime from November to March. As a result, the quality of the forage is better in St. Croix.

"We're finding in our evaluations that Senepol in Florida look much the same as the Brahman with respect to reproductive efficiency. Senepol do contribute a docile temperament and may have better carcass quality.

"But there are lots of other breeds of tropical cattle around the world, so we certainly haven't given up. And whatever we find may also work throughout the humid South including the Gulf states, as well as in the arid Southwest."

That optimism extends to improving the performance of the standard Brahmans as well as exotic breeds. Chase hopes to show how careful management of cows' time with their calves—and consequently reduction of the physical demands of nursing those calves—can boost the mothers' chances of quickly becoming pregnant again.

To demonstrate this, he's started a study involving about 50 first-calf Brahman heifers divided into three groups. One group eats hay, molasses, and 2 pounds of 20-percent crude-protein feed cubes per day, and has unrestricted access to their calves. The second group has the same diet, but their calves are allowed to nurse only 30 minutes to an hour each day, beginning 30 days after birth.

The third group gets 5 pounds of protein feed cubes, rather than the 2 pounds offered the other groups, but has unrestricted suckling.

Results of this study are still pending, Chase says. "But in studies at the Texas Agricultural Experiment Station at Overton, it's been shown that you can reduce the postpartum interval in first-calf crossbred Brahmans by 100 days by restricting suckling, and the weaning weights of those restricted calves are no different than other calves," he says. "We also know that increased nutrition will shorten the postpartum interval."

This technique may not work across the board for all Brahman mothers, he adds.

"Brahmans come in small, medium, and large frame sizes, and it looks like large-frame heifers simply have a longer postpartum interval than the small ones," says Chase. "Restricting suckling may not work as well on the large-frame heifers, because it takes so much more nutrition just to maintain that cow."

On the forage side of the equation, plant physiologist Mimi J. Williams hopes to find high-quality forages that will thrive in Florida's surprisingly difficult conditions.

"Our winter temperatures are suited for growing cool-season species, but we don't have the rainfall to support them," Williams says. "That limits us to tropical species like bahiagrass or bermudagrass."

In a switch from the usual scenario of lush spring grasses, cattle producers in Florida find themselves with plenty of good-quality forage in early summer, plentiful but lower quality forage in late summer and fall, and a shortage of grazing in the spring. "In April and May, it's very dry here. There may not be enough for the animal to eat," says Williams.

As with the Brahman cattle, Florida has a "workhorse" forage in bahiagrass. Bahiagrass has proven to be one of the most persistent of grasses and already grows on about 2 million acres in Florida. But its dry-matter production can be skimpy, as little as 3 tons per acre compared with 6 tons or more per acre from bermudagrass.

"Bahiagrass is the poor man's bermudagrass," says Williams. "Bermudagrass has to be propagated vegetatively—sprigged—but bahiagrass is grown from seed. Bermudagrass generally has a higher nitrogen requirement, while bahiagrass will generally persist without nitrogen fertilization."

Unfortunately, bahiagrass' nutritional quality leaves much to be desired. "The only time it's better than marginal is from April to the end of June," says Williams. "But it does produce when something else might not."

MIMI WILLIAMS

Senepol cattle can also take the subtropical temperatures and are resistant to parasites. (K-3714-2)

Grasses Gaged to the Sunshine State

A promising addition to Florida's forage arsenal is a non-seed-producing variety of the peanut plant. As a legume, the peanut has higher levels of protein—up to 18 percent—and as much as 65 percent digestibility.

By comparison, young bahiagrass offers a maximum 15 percent protein, if it's treated with nitrogen fertilizer, and digestibility of about 55 percent. When mature, bahiagrass doesn't often contain more than 6 percent protein and may be only 40 percent digestible.

While bahiagrass needs nitrogen fertilizer to do its best, the peanut is able to fix its own, converting nitrogen from the air into a form that the plant can use. This cuts down on nitrogen fertilization needs, production costs, and the likelihood of groundwater pollution by fertilizer.

"Dry matter yield on peanuts has been 3 to 6 tons per acre per year, and the cattle have gained about 2 pounds a day on them, compared with a pound a day on bahia pasture," says Williams. "We've grazed cattle on the peanuts from April to September, and there was no summer slump; the cattle continued to gain.

"Potentially, this could work anywhere in the Coastal Plain, into the Carolinas, and all the way across into Texas," she says. "The dairy industry could use this as well as the beef cattle industry; it's great for replacement calves."—By **Sandy Miller Hays**, ARS.

Andrew C. Hammond, Chad C. Chase, Jr., and Mimi J. Williams are in USDA-ARS Subtropical Agricultural Research, 22271 Chinsegut Hill Road, P.O. Box 46, Brooksville, FL 34605-0046 (904) 796-3385. ◆

It's Drawn in Charcoal

Picture of First Century Agriculture

It looks exactly like a walnut you'd buy in any grocery, down to the crinkles in the nut meat where the shell has broken away. Except this walnut is black, not brown, and it lay buried in volcanic ash at Pompeii, Italy, for 1,905 years.

This walnut—also called the Persian nut and Jove's acorn by the Romans—is one of hundreds of plant specimens from Pompeii and the surrounding areas that were identified during the past 20 years by Agricultural Research Service botanist Frederick G. Meyer.

Buried plant material normally decomposes in a few months to a year. But in A.D. 79, the volcano Vesuvius erupted, burying the city and its inhabitants in a shroud of ash and pumice averaging 22 feet thick.

At Pompeii, Meyer explains, heat from the ash and pumice converted cellulose plant fiber into carbon. Left behind were brittle, coal-black plant lookalikes that appear carved from charcoal briquets—often right down to details of stems and seeds.

Heat from the eruption carbonized—to varying degrees—gardens, crops, and even stored fruits, vegetables, and grain.

In the 1960's, Wilhelmina Jashemski, a professor of ancient history (now retired) at the University of Maryland, sought Meyer's expertise in identifying plant specimens that had been dug up at Pompeii as far back as the late 1800's.

Meyer, who works at the U.S. National Arboretum at Washington, D.C., has identified 25 species of common food crops carbonized by the eruption, including hazelnuts, figs, olives, broadbeans, chickpeas, barley, lentils, foxtail millet, carob, emmer (the ancestor of wheat), onion, and garlic. He recently published this information in a chapter in *Studia Pompeiiana & Classica.*

"Vesuvius created an incredible store of information about the history of agriculture, which has only been documented in the last few years," he says. "And Pompeii is the only site in the ancient world that has this large a collection of food plants giving a record of what the Romans were eating in the first century A.D.

"The carbonized specimens give us a detailed look not only at what the residents grew in their gardens but also what grew wild, what food and plant products were stored, and how they were stored. We've identified enough grapes and vineyards to confirm that winemaking was an important industry."

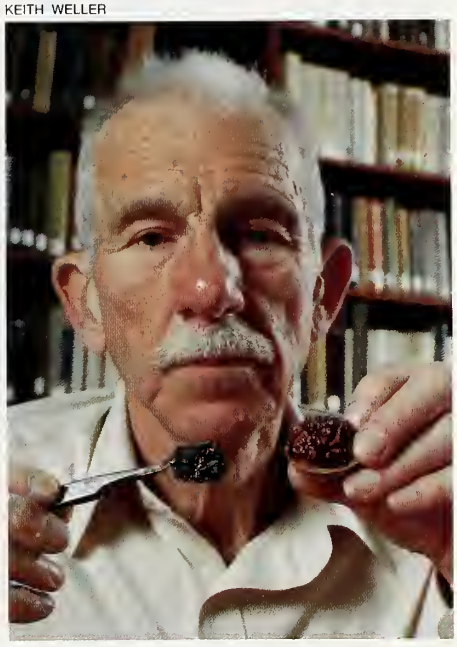
Dates that were found stored in two-handled earthen jugs called amphoras could not have been grown in the area's cool growing season. "Most likely, the dates came from Egypt," Meyer says.

Emmer wheat made "the sweetest bread," according to Pliny the Elder (A.D. 23-79), whose writings are considered the best authority on food plants of the area and era. Meyer adds emmer is still sometimes used by wheat breeders as a source for disease resistance when they create new wheat hybrids.

Walnuts were found carbonized in large numbers as well as depicted in wall paintings in the Villa of the Mysteries, a luxurious home in Pompeii. "Romans considered walnuts difficult to digest and did not rate them highly as a food," Meyer says, "but they used the shell for dyeing wool and the young nuts to dye hair red."

Diggers also found a 1-ton cache of pomegranates, far too many and far too small and green to have been picked for eating. "But green pomegranates are high in tannic acid, which is used to tan leather. This cache was probably destined for a leathermaker," he says.

KEITH WELLER



Plant taxonomist Frederick Meyer compares a carbonized walnut found in Pompeii to a modern-day one. (K-3081-14)

In addition to the food plants, Meyer and others identified more than 200 plant species including wildflowers, weeds, and other plants depicted in wall paintings.

Many of the sites were gardens—ranging from 9 feet square to about an acre. "Pompeii must have been a very green city," he says.

Meyer has also identified plants on many wall paintings for which no carbonized remains have been found. "For example, one wall painting clearly pictured a hart's tongue fern, a handsome fern still found growing in the Pompeii area."

Meyer is something of a historian himself. He is writing a book about woodcut illustrations published in the 1230's to describe plants used as herbal medicines.—By **J. Kim Kaplan,** ARS.

Frederick G. Meyer is at the U.S. National Arboretum, 24th and R Streets, N.E., Washington, DC 20002 (202) 472-9100. ◆

PERRY RECH

In his own backyard garden, botanist James Duke inspects what many consider a weed—St. Johns wort. Long used in folklore as an antidepressant, this herb, also known as Klamathweed, contains two compounds that are being investigated for anti-AIDS potential. (K-3709-8)

For Alternative Crops—He's the Duke

His business card says "Economic Botanist." "That's what they call you when you work on crops that are on the fringe of economic importance—crops that hardly anyone has ever heard of," wryly explains Agricultural Research Service scientist James A. Duke.

What Duke actually works on at the ARS National Germplasm Resources Laboratory in Beltsville, Maryland, is alternatives—crops that a farmer could grow in place of conventional ones such as wheat or corn that are in oversupply. Or that could fill an important void such as a source for a cancer-curing drug or a tick repellant.

But Duke is not a plant breeder; he is a plant finder. He exchanges cuttings and seeds from researchers, seedbanks, and breeders around the world. Occasionally, he even collects them himself from the wild.

Once he obtains the germplasm, the material is catalogued and added to collections at the appropriate ARS plant introduction station or other germplasm repository. Information about the potential crop is also added to Duke's own extensive files.

"My collecting plugs up some of the holes in the germplasm system," Duke says. "We have curators who tend to collect different strains of crops such as soybeans and potatoes. But the odd crops—unusual ones that don't belong anywhere in particular and maybe are new opportunities or on the fringe of the profit margin—that's what I'm concerned with."

For example, someday there might be farmers profitably raising a plant that is now considered a weed—St. Johns wort.

About 2 years ago the National Cancer Institute (NCI) came to Duke for assistance because it was interested in St. Johns wort, which has a long history in folk medicine for treating nervous disorders, burns, and urinary infections. Two compounds in the weed have been found to strongly inhibit the AIDS virus.

While species of St. Johns wort are native to Europe, West Asia, and North Africa and naturalized in North America and Australia, it hadn't been systematically collected for inclusion in a germplasm bank.

Since then, Duke has collected five different species of the weed that grew wild along the highway near his home in Fulton, Maryland.

"After a while, you get so you can recognize a species even at 50 miles per hour," Duke says.

Different species appear to have varying levels of the active chemicals, which make collecting them important to improving its possibilities as a pharmaceutical crop.

As fascinating as locating potential medicinal plants is, Duke's real focus is alternative food and energy species. He has files on almost 1,000 different crops from which someone might make a living.

"You don't have to grow wheat or soybeans. But there isn't a large market for most of these alternative crops, so you need lots of different possibilities."

Take basil, for example. "If a farmer near Omaha wanted to get out of corn, he could make a living with basil," Duke says. "Each major city can support a basil grower, but probably only one."

He recently spent a week in Sao Tome, an island off the coast of North Africa, helping the local government decide if they could grow black pepper as a commercial crop. The island is looking for an export to help the local economy.

Duke found it would be ecologically possible for it to grow there, but the economics of it were questionable. "In an up market, they could make money; in a down market they'd lose money," he says.

There are other crops in Duke's files. "I have a file on a firewood tree species that grows very fast and burns well that could be an important crop for many Third World countries," he says. "And then there is a plant that has a resin in it that could be used as a fuel in diesel engines. If energy costs rise, it could become an economically important crop."

As an alternative crop to tobacco in North Carolina, Duke has been collecting varieties of evening primrose. Oil from the evening primrose flower is a major source of gamma-linolenic acid. [*Agricultural Research*, March 1990, p. 20] This fatty acid is a precursor of prostaglandin E1 and is thought by some to be able to abate the symptoms of several illnesses. It is best known as a treatment for atopic eczema.

"I've exchanged evening primrose seed with people in Israel, Holland, and Canada, so as the demand for the oil increases, we can offer germplasm for making improvements in the crop," Duke says.

PERRY RECH

You have to stop and smell the flowers or in this case, the bee balm *(Monarda didyma)*. Aromatic leaves of this mint, also known as Oswego tea, were used as a tea substitute during the American Revolution. (K-3709-32)

Right now, about 400 acres in North Carolina are being planted in evening primrose, and each year the number grows "about on a par with the growth in demand."

"Jim Duke's extensive files on alternative crops and his network of contacts for obtaining germplasm are invaluable," says Henry Shands, ARS National Program Leader for Germplasm. "Changes in society and changes in the economy have made alternative crops more important than ever. And when one of our scientists needs information on a nontraditional crop, Jim Duke usually has the answer."

St. Johns wort is not the only potential AIDS fighter whose germplasm Duke has gone after.

A reference in some medicinal plant literature led him to seek out samples of the Moreton Bay chestnut, an evergreen legume that grows in the rain forests and along stream banks in northeastern Australia.

It is one of the best sources of castanospermine, a compound that appears to halt reproduction of the AIDS virus.

Duke brought the chestnut's seeds from Australia, so it will be available if needed for research or agronomic studies. If the compound is useful against AIDS, the plant could be a lucrative alternative crop possibly suited to Texas, Arizona, Florida, California, and Hawaii.

In 1987, before its potential anti-AIDS activity was announced, castanospermine was priced at $23 per milligram. "That comes to $9 million per pound, if a pound were salable at the milligram price," Duke says.

Some Moreton Bay chestnut seeds yield 0.3 percent of the compound, about 3,000 parts per million, while other seeds only yield 2 ppm. "The difference could be environmental, genetic, or just in the extracting procedure. We need to collect germplasm from different plants that contain the compound," he says.

In March of 1989, Duke was phoned by a friend in New York, a "guerilla warrior" against AIDS, who told Duke they had had some luck using two species of Chinese

"Changes in society and changes in the economy have made alternative crops more important than ever. And when one of our scientists needs information on a nontraditional crop, Jim Duke usually has the answer."

gourds—*Momordica* and *Trichosanthes*—as an underground treatment.

Gourds often contain cucurbitacins, which are very active physiologically, according to Duke. His friend labeled the AIDS-fighting chemical "Compound Q." It is a dangerous compound, Duke cautions.

Both of the gourds are listed as official drugs in the Pharmacopeia of the People's Republic of China and have been used in Chinese folk medicine since A.D. 300.

Clinical trials using a highly purified protein from *Trichosanthes kirilowii* have been approved by the U.S. Food and Drug Administration. Duke now has germplasm for both Chinese gourd species.

Recently, he submitted wild-harvested *Huperzia lucidula* for alkaloid analysis as a possible treatment for Alzheimer's disease. Plants in the Huperzia family (clubmosses) have been used as medicine in China for centuries for such diverse ailments as muscle cramps, hemorrhoids, and pneumonia.

"But *H. lucidula* is relatively easy to cultivate compared to most other Huperzia species," he said. "So it very well might become a useful, albeit specialized, crop."

He has obtained spores of a related species from Pakistan that might even be cultivable in tissue culture; he now has the plant growing.

In his work with alternative crops, Duke has become a strong advocate of preserving the biological diversity of the rain forests, "preferably as they exist in nature.

"We have no idea of all that's growing there that has never been tested—a new food crop, a new cure for a disease, a tick repellant, the genes to improve crops we already grow. Nobody knows everything that's out there, and we may lose much before we learn," he explains.

Duke was recently in Ecuador, a member of a team that is trying to put an economic value on crop relatives that grow in the rain forest reserves but aren't cultivated.

REGINA O. HUGHES

St. Johns wort

Tomatoes, hot peppers, and potatoes originated as wild plants in Latin America, and there are still wild relatives of these crops that haven't been looked at.

While Duke spends a lot of his time on the telephone and updating computer files on growing crops from jojoba to licorice, he looks forward to the time he spends cultivating some of the germplasm he collects.

Growing in his own backyard garden as well as in a greenhouse at his Beltsville lab is a wild mountain mint that he collected that may be the best source of pulegone, the major ingredient in pennyroyal oil. This highly pungent compound has been found to repel fleas and birds and is being looked at as a tick repellant.

"The mint is a woodland species. When I crushed its leaf, the strong odor of pulegone captured my attention," Duke says.

"I spend my winter with the computer, but the rest of the year I'm out crushing leaves and sniffing them."—By **J. Kim Kaplan,** ARS.

James A. Duke is with the USDA-ARS Germplasm Resources Laboratory, Rm. 133, Bldg. 001, Beltsville Agricultural Research Center, Beltsville, MD 20705 (301) 344-4419. ◆

Water Weeds Tamed With Promising Compound

Weeds that clog marinas, snarl fishing lines, entangle swimmers, and choke irrigation canals might be thwarted with a chemical that's more effective—yet just as environmentally safe—as some other herbicides already okayed for that use.

Tests in greenhouses and irrigation canals show that the herbicide, bensulfuron methyl, works in two ways to attack some of America's worst water weeds, says ARS plant physiologist Lars W.J. Anderson at Davis, California.

First, the compound stunts growth of young plants, such as hydrilla, weedy plague of waterways in Florida, Texas, Arizona, and California. It works just as well on Eurasian watermilfoil, an increasingly troublesome pest in northern and midwestern states, and other problem species such as sago pondweed and elodea.

Keeping these unwanted plants in check gives other vegetation—types that fish and beneficial aquatic insects prefer for their surroundings—a better chance to outcompete the weeds.

Second, the chemical blocks weeds such as hydrilla from forming vital reproductive structures. Normally, hydrilla produces tiny, budlike turions at junctures where leaf and stem meet. Turions start new plants, enabling hydrilla infestations to spread.

Nor can hydrilla plants exposed to the chemical form tiny tubers in the bottom mud. These tubers, capable of surviving for up to 10 years, give hydrilla a means to survive through the winter and through longer periods under dry conditions.

Importantly, moderate doses that Anderson is testing in northern California sites, including fish-ranch ponds, private and public lakes, and irrigation canals, won't kill weedy pests outright. That's a benefit, he says. A quick kill can leave a mass of smelly, rotting vegetation that uses up oxygen that fish need. "With most aquatic weeds," Anderson explains, "you usually don't want to completely or even nearly kill all the growth. You just want to keep plants low-growing and under control."

Because it is very safe to mammals, fish, insects, and other life, the compound might be ideal to team with biological controls—such as fish, insects, or fungi—that could be recruited to destroy the weeds, Anderson says.

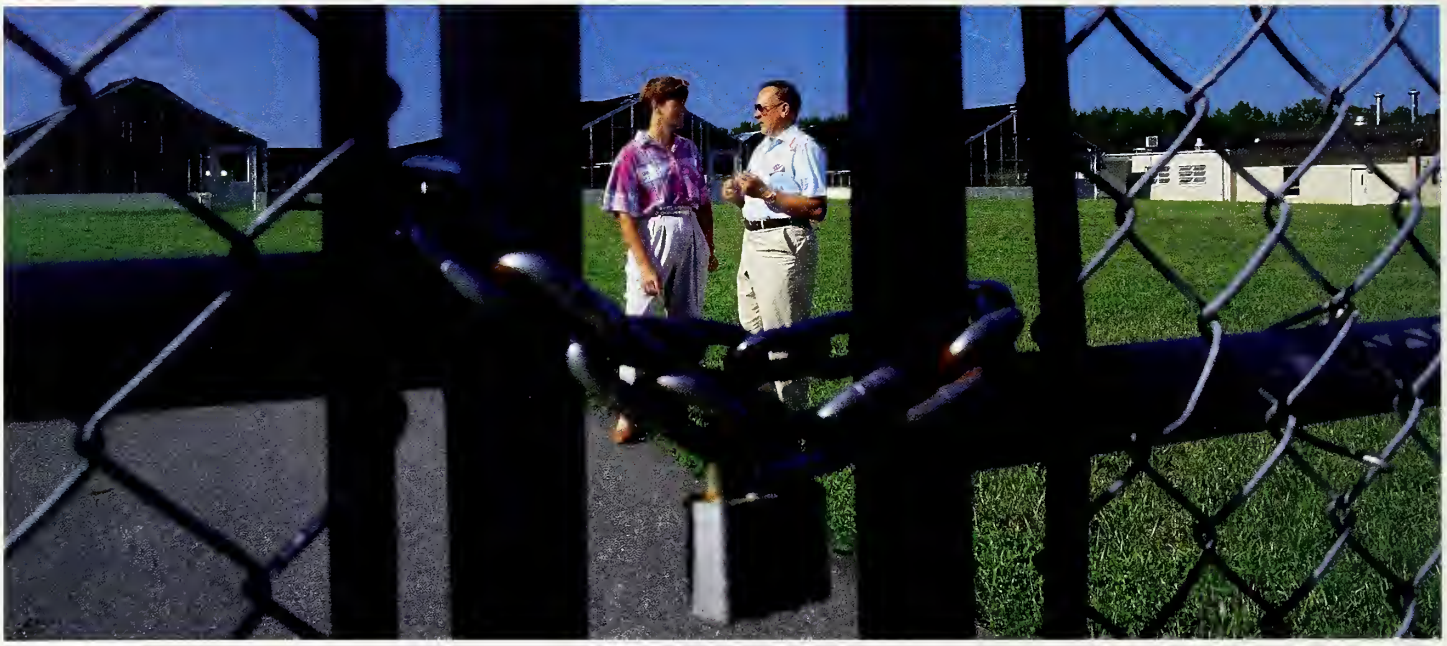
Bensulfuron methyl is already approved for use on weeds that infest rice paddies. But the Davis team was the first to discover and show the chemical's potential to block growth and reproduction of other aquatic weeds. Their tests, and others nationwide, will be used by the manufacturer, Du Pont, in seeking U.S. Environmental Protection Agency approval for this new use of the promising chemical.

Battling weeds costs western states an estimated $50 million annually. Among other states, Florida probably foots the biggest bill—its yearly tab for fighting hydrilla is about $23 million.—By **Marcia Wood,** ARS.

Lars W.J. Anderson is with USDA-ARS Aquatic Weeds Control Research Unit, Botany Department, University of California, Davis, CA 95616 (916) 752-6260. ◆

Hydrilla, an aquatic weed, branches profusely. Just one fragment from this shoot can form roots and produce a new plant. (K-1290-13)

KEITH WELLER



Ellis Island for Plants

"Before a plant that could bring dangerous diseases into this country is allowed in, it must be certified free of harmful, foreign pathogens—that it isn't harboring a disease to which plants here have no defense."

Dutch elm disease, which entered the United States in 1931, has killed millions of American elm trees.

But plum pox—a disease that has devastated fruit orchards in Europe—has been kept out.

Understanding the difference between an exotic disease that has swept through the United States and one like plum pox that has been stymied is the work of the ARS National Germplasm Resources Laboratory.

One of this laboratory's missions is to make sure plants entering this country are healthy—free of diseases not present in the United States.

"What we are is sort of an Ellis Island for plants," explains Howard E. Waterworth, an ARS pathologist at the quarantine facility.

"Before a plant that could bring dangerous diseases into this country is allowed in, it must be certified free of harmful, foreign pathogens—that it isn't harboring a disease to which plants here have no defense."

A strict quarantine examination such as those the Animal and Plant Health Inspection Service (APHIS) and the ARS lab now conduct might have kept Dutch elm disease out of this country, Waterworth says.

Even though the first U.S. quarantine law was passed in 1912, there were no tough inspections. The damage that resulted from the introduction of the white pine blister rust, the chestnut blight fungus, and the citrus canker bacterium provided the impetus for that law.

In 1929, several years before Dutch elm disease hit the United States, the American Phytopathological Society Committee on Investigation of Foreign Pests and Plant Diseases recommended that federal officials investigate ways to prevent or control the possible introduction of foreign diseases. They listed nine categories of diseases that were "because of geographical, crop, or commercial conditions likely to be introduced here." That list specifically named the elm diseases of Europe.

◀ **At the new Beltsville plant quarantine facility (background), foreign germplasm is tested for hundreds of pathogens upon arrival in the United States. (K-3574-9)**

▶ **Plants from overseas are examined several times a year for diseases. Here, in a quarantined screenhouse, plant pathologist Howard Waterworth examines apricot plants for late-season virus-like disorders. (K-3570-9)**

KEITH WELLER

But by the early 1930's, before new regulations were effected, Dutch elm disease had already entered the United States and had begun killing trees in the eastern United States.

Congress established the current quarantine and inspection arrangement with the Plant Protection and Quarantine Program in 1971 as part of APHIS. The ARS plant quarantine lab carries out all the testing for APHIS, which actually certifies plants as "free to go" based on ARS' test results.

There are three categories of plant quarantine: restricted, post-entry, and prohibited.

Restricted plants require only a visual inspection by APHIS inspectors at the port of entry into the United States. Seeds of most forage, vegetable, and flower species fall into this category.

Post-entry plants can be kept by the person importing them and observed on their premises for signs of disease or insects by state or federal inspectors with APHIS' permission. But the plants cannot be distributed to others until formally released by quarantine officials.

Prohibited plants *must* be sent to a quarantine facility for checking.

Less than 3 percent of the world's plant species fall into the post-entry and prohibited categories.

But that 3 percent includes all the vegetatively propagated pome and stone fruits—plums, apples, pears, cherries, peaches, and apricots, among others—as well as grapes, sugarcane, rice, berries, sweetpotatoes, ornamental and lumber trees, and decorative and forage grasses.

Sometimes the quarantine applies only to plants from a region where a disease is known to occur.

Coconut trees from anywhere except Jamaica are in the prohibited category because they could bring in cadang-cadang disease or lethal yellowing disease. But coconut trees from Jamaica that have been bred to be resistant to the disease are merely in the restricted category.

It is always the chance that a plant could bring in a disease that is important, Waterworth says.

Junipers from Austria, Finland, or Romania are in the prohibited category because plants from those countries could be harboring needlecast disease. Junipers from anywhere else, where needlecast disease is less likely to occur, fall into the post-entry category.

Similarly, strawberries from Australia, Austria, Czechoslovakia, France, Great Britain, Italy, Japan, Lebanon, The Netherlands, New Zealand, Northern Ireland, The Republic of Ireland, Switzerland, and the USSR are all in the prohibited category. From anywhere else, except Canada, strawberries are in the post-entry category. There are no restrictions on strawberry plants from Canada.

As soon as plants in the prohibited category arrive, they are immediately inspected by APHIS and then shunted off to the ARS quarantine laboratory, which has facilities in

KEITH WELLER

◀ **Technician Pat Boyd uses sterile technique to collect samples for lab tests. (K-3572-7)**

▶ **Technician Wayne Claus conducts preliminary tests to determine if a new plant should be quarantined. (K-3575-7)**

Beltsville and Glenn Dale, Maryland. Citrus crops are quarantined at Gainesville, Florida, or Riverside, California, and grapes are sent to Davis, California, or Geneva, New York, because of the expertise in these crops at those locations.

Once a specimen arrives at the quarantine facility, it undergoes extensive screening for disease before it can be released to the researchers and breeders awaiting it.

Testing can take as long as 5 years; researchers and plant breeders have been known to get impatient. Many diseases can only be checked for by seeing if a plant gives a sensitive indicator plant a disease, Waterworth explains.

Since symptoms are not usually apparent at first, special care must be taken to be sure that an infected plant does not contaminate a healthy neighbor in quarantine.

This care can create an incongruous picture. Lab technician Pat Boyd must scrub up like a doctor heading for the operating room before she can conduct indicator plant tests in a greenhouse full of plants and dirt.

"You have to be very careful not to spread disease yourself, since we're trying to find out if these plants are carrying pathogens," she says.

She grinds up leaves from a quarantined plant and prepares a fluid from it to paint onto a plant of an indicator species known to be sensitive to a particular disease. Cucumbers, beans, and tobacco are common indicator plants.

High Tech, Low Tech

But for some diseases, the only way to diagnose them is to graft the cutting and then look for symptoms. There is no shortcut in these cases.

"Symptoms for a disease like plum pox virus often don't show until a plum tree begins to fruit—3 or 4 years after planting. So that's how long we have to wait to be sure," Waterworth says.

For other diseases, diagnostic tests exist, using serology and monoclonal antibodies, electron microscopy, or DNA probes. These high-tech methods are much faster and usually more specific for identifying the presence of a particular pathogen.

For most plants, the testing is a mix of high and low tech. For example, before almond plants are certified for open distribution, they must undergo—

- visual inspection for general signs of insects or disease
- serology lab tests to check for plum pox disease, prune dwarf virus, *prunus* necrotic ringspot virus, and tomato ring spot virus
- testing on herbaceous plants as indicators for American nepovirus, apple chlorotic leafspot virus, and ilarviruses
- grafting onto Elberta peach seedlings to test for almond bud failure agent, apple mosaic virus, peach mosaic virus, and others
- grafting onto flowering cherry trees to test for prune dwarf and necrotic ringspot
- grafting onto Peerless almond

KEITH WELLER

trees to test for almond bud failure agent, almond leaf scorch bacterium, and unknown almond pathogens.

"The test list is similarly long for most other species that have to go through our lab," Waterworth says.

Some of the graft testing and growing out takes place in greenhouses, while other tests involve planting or grafting the incoming variety outdoors.

Rice presents a unique problem because specimens must be planted at least 3 feet apart during testing to prevent cross-contamination. So several greenhouses are filled with mini-rice paddies each in a 2-gallon plastic bucket.

"We also must take care that no disease escapes from the quarantine lab itself," Waterworth says. "Stone fruits—cherries, peaches, plums.—are the hardest to deal with."

To prevent insects from reaching a stone fruit tree in quarantine and possibly carrying a disease to local orchards, it must be grown in an enclosed superfine mesh screenhouse.

In addition to the rice, right now the lab is also testing, among other things, about 100 specimens of apricots from Pakistan. Adding to the bounty, over 100 specimens of currants and gooseberries came in from Great Britain when, in a major budget cutback, it closed a small fruit germplasm repository last year.

Apple Dapple Disease

Scientists are always delighted when they can switch from the slow, old-fashioned indicator plant tests or the even slower grow-it-out-and-look method to faster, more specific diagnostic tests.

ARS plant pathologist Ahmed Hadidi, who is part of the quarantine lab staff, has already developed a test for apple dapple disease that can tell in a few days whether a tree is infected. It's a disease that's devastated orchards in China and Japan.

Apple dapple disease is caused by the apple scar skin viroid, a smaller-than-a-virus particle that possesses the genetic material of a virus but lacks its protein coat. It was among the diseases that could previously be diagnosed only by waiting 3 to 5 years for symptoms to appear on the fruit.

Hadidi developed a DNA test probe by genetically engineering a copy of the apple scar skin viroid. He spots a nucleic acid extract of tissue from an apple tree onto a membrane which is then immersed in a solution containing millions of radioactively labeled copies of the synthetic viroid.

If a dark spot appears on photographic film held against the membrane, the viroid has matched up with the synthetic copies and is present in the tree.

"No false positives or negatives occur and you get an answer in just a few days instead of waiting years," Hadidi says.

Hadidi had developed a similar DNA probe for tomato ringspot virus. And he is working on probes for other diseases.

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Technician Ray Mock grafts foreign sweetpotato germplasm onto a virus-sensitive indicator plant. (K-3576-13)

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Rice germplasm from the Philippines is monitored for fungal diseases before release to U.S. breeders. (K-3567-16)

If a plant is found to be carrying a disease, the quarantine lab doesn't give up on it. Attempts are made to get a disease-free bud from the growing tip of a plant or to take seeds that may be clean.

Diseased specimens are removed and run through a large autoclave to be destroyed. The autoclave can handle tree trunk sections as long as 5 feet at one time.

In a typical year, 550 specimens are ready to present to an APHIS official who will certify them as safe.

New Germplasm, Come and Get It

Each spring, the quarantine lab publishes a catalog of some of the plants that have been released for distribution. "Sort of a come-and-get-it list for germplasm collectors, researchers, and breeders," says plant pathologist Suzanne S. Hurtt. "The catalog and specimens are not available to the general public."

The USDA germplasm collections get first call on available material.

Some may ask, why take any chance at all of allowing an exotic disease to enter the country by admitting any possible carriers?

"In one of the specimens that comes through here could be the genes that could really improve our varieties. One of the specimens could provide drought tolerance or cold hardiness or disease resistance where the trait doesn't currently exist," Waterworth says.

Looking for new germplasm usually means obtaining foreign plants because very few of our common crops originated in North America, Waterworth adds.

"Peaches and soybeans originated in China, and rice originated in India, for example. If you want to find the wild relatives and ancestors that might have the genes to improve the varieties we grow here, then that's where you need to look—where they came from," Waterworth says.

Are Quarantines Worth It?

One thing to keep in mind though, Waterworth says, is that quarantines are rarely, if ever, totally effective in the long run. "But they can buy time, delaying the introduction and establishment of an exotic disease."

Delays are especially valuable if the time can be used to learn more about a disease and the agent that causes it—information that can be used to fight it or even create a resistant variety.—By **J. Kim Kaplan,** ARS.

Howard Waterworth, Suzanne S. Hurtt, and Ahmed Hadidi are at the USDA-ARS National Germplasm Resources Laboratory, 11601 Old Pond Drive, Glenn Dale, MD 20769 (301) 344-3003. ◆

Irrigated cropland in California's Imperial Valley. (K-1918-10)

Measuring Salinity Fast

Salts continue to take their toll on U.S. irrigated land. An estimated 4.5 million acres out of 8.6 million that are irrigated in California are damaged to some degree by salinity. Similar problems pervade much of the Southwest.

Estimates for foreign countries are even bleaker. India may have up to 35 percent of its irrigated land seriously salinized, while one-quarter to one-half of South America's irrigated acreage may be harmed by salts.

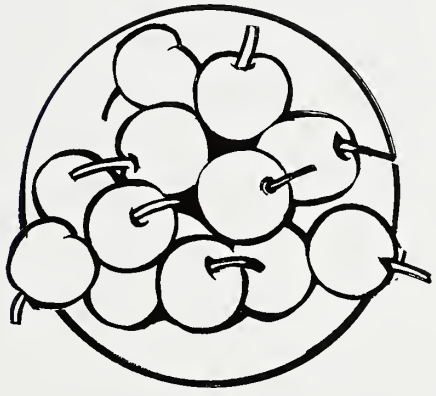
In this country, better estimates may soon be possible thanks to a new measuring technique developed by an Agricultural Research Service soil scientist in Riverside, California. The technique should also provide other researchers with better means to find ways to halt or at least slow the process of soil salinization because they can gather more information, faster.

ARS' James D. Rhoades says he can now determine the salinity of soil samples in 60 seconds, while previous tests took up to 12 hours. The new technique that he developed at the U.S. Salinity Laboratory uses battery-operated measuring devices so that tests can be done in fields.

This fast, accurate test will help scientists more precisely map large saline areas. If they detect much variation within a field, they can gather more samples while they are doing the testing. Alternatively, they can limit sample numbers if the differences are few from one test site to another.

Key to the new test is measurement of the weight and electrical resistance of soil paste made by mixing the soil sample with water and then placing it in a cup of known volume. Scientists then calculate soil salinity based on their recently developed model of electric flow through soils.—By **Dennis Senft,** ARS.

James D. Rhoades is director of the USDA-ARS U.S. Salinity Laboratory, 4500 Glenwood Drive, Riverside, CA 92501 (714) 369-4814. ◆



Estimating Fumigant Residues

A new method to gauge fumigant residues in fruits and other agricultural products could lead to improved safety for handlers, shippers, and consumers.

ARS chemist Charles R. Sell devised a computer-based, mathematical model to estimate how much methyl bromide, a widely used fumigant, remains in produce after fumigation. Residues of this highly penetrating toxic gas may seep from commodities during storage or transport, so it's important to make sure the produce is safe to handle and consume after fumigation.

Currently, fruit or other produce is tested directly—by crushing and blending it and measuring the methyl bromide present with a gas chromatograph. In contrast, the new model measures residues indirectly. An instrument determines the amount of methyl bromide in the exhaust air blown from the fumigation chambers and then transmits that number to a computer. The model computes the amount of methyl bromide remaining in the commodity, taking into account a host of variables, such as type and amount of fruit, temperature, and other conditions.

Sell and co-inventor Mark A. Weiss verified the model's accuracy by comparing estimated values with actual measurements. Both researchers are with the Fruit and Vegetable Insect Research unit in Yakima, Washington.

Codling moth larvae and eggs may lurk in cherries and apples after harvesting, and foreign consumers, notably the Japanese, don't want the pest introduced to their country. Methyl bromide provides an effective and accepted treatment for eliminating the hidden pests. But Japan requires that residues of methyl bromide in fumigated commodities not exceed 10 parts per billion.

This innovation will improve current fumigation practices by speeding up residue measurements, Sell says. He's applied for a patent on the new model, which can be scaled up for commercial operations.—By **Julie Corliss,** ARS.

Charles R. Sell and Mark A. Weiss are with the USDA-ARS Fruit and Vegetable Insect Research Unit, 3706 W. Nob Hill Blvd., Yakima, WA 98902 (509) 575-5967. ◆

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